The supernova that destroyed a galaxy

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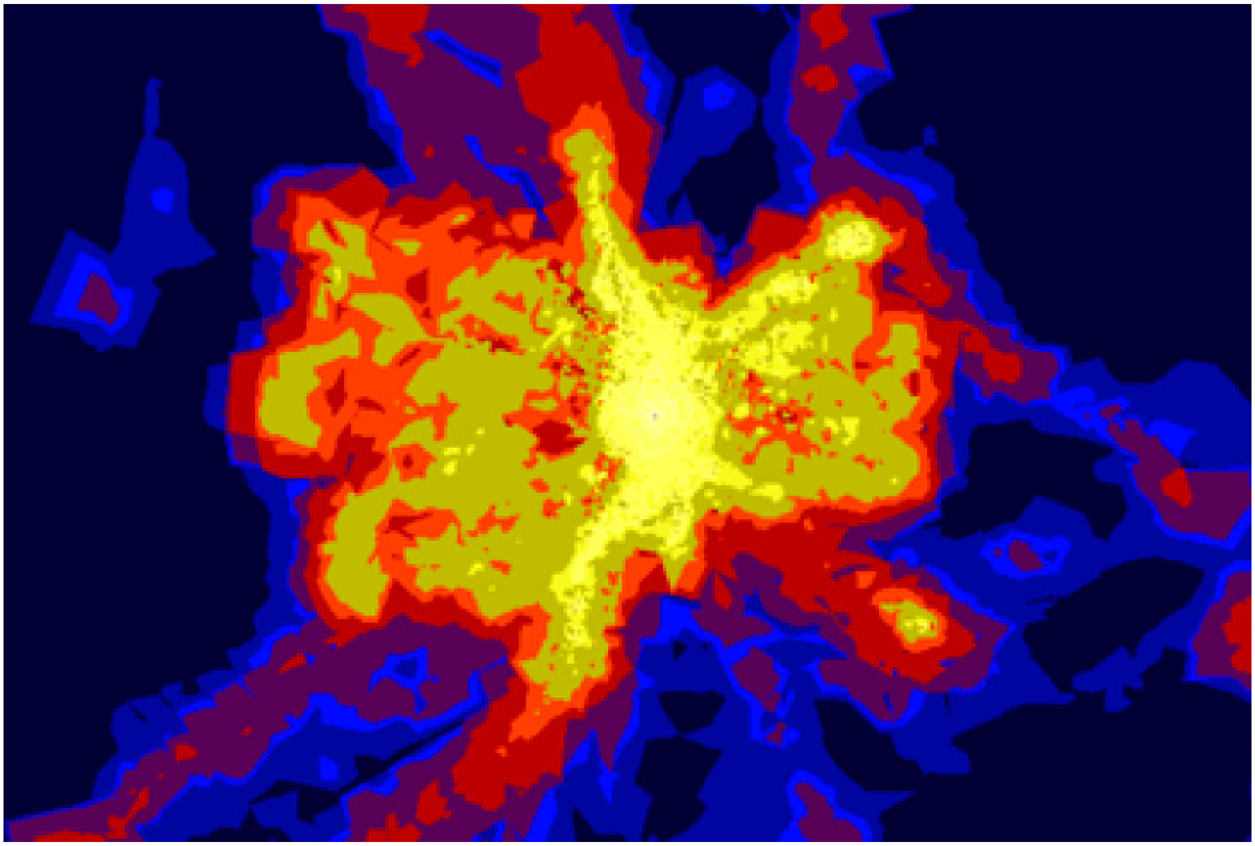

New supercomputer simulations by Los Alamos scientists and collaborators capture in unprecedented detail extremely powerful supernovae explosions in the early universe and their effect on the nascent galaxies that gave birth to them. The *New Scientist* highlights the supercomputer simulations that reproduced the energetics of the explosion from the surface of the star to its escape into the intergalactic medium. The research may solve the long-standing puzzle of how supermassive black holes were formed in the centers of some galaxies less then a billion years after the Big Bang. The *Astrophysical Journal* has accepted the research for publication.

Significance of the research

The formation of primordial stars and primitive galaxies ended the cosmic Dark Ages a few hundred million years after the Big Bang and began to transform the universe from a cold, dark, featureless void into the vast cosmic web of galaxies observed today. A few of these galaxies formed in the presence of strong ultraviolet (UV) fields that destroyed all of their molecular hydrogen, preventing them from forming stars until they reached 100 million solar masses. Then they began to cool sharply, and their gas catastrophically collapsed into their centers, in some cases forming stars that were hundreds of thousands times the mass of the Sun. The usual fate of such stars is to collapse to black holes with little or no explosion. However, some of these ancient stars instead exploded with nearly 10,000 times the energy of supernovae today, making them the biggest explosions in the universe.

The Los Alamos simulation is the most realistic cosmological supernova simulation ever performed of this process. The team determined the effect of supernova in different density regions and showed how certain conditions could fuel the rapid growth of a young black hole at the center of the protogalaxy. This finding may solve the puzzle of how supermassive black holes came to be in the centers of some galaxies less then a billion years after the Big Bang. The simulations also show how heavy elements of carbon, oxygen, and silicon could mix with primordial hydrogen and helium gas and later pool back into the protogalaxy, perhaps forming low-mass stars that may still exist in the universe today. Future observational campaigns may discover such stars, which may yet bear the ashes of these ancient explosions.

Research achievements

The team modeled the early stages of the explosion with the LANL radiation hydrodynamics code RAGE to simulate the extreme matter and radiation flows when the supernova shock erupts through the surface of the star and expands into the protogalaxy. Then they mapped the blast profiles from these runs into a much larger cosmological hydrodynamics simulation that followed the propagation of the shock into the protogalaxy in which the star originally formed. The scientists evolved the supernova explosion for about 100 million years to study its effects on the primeval galaxy.

This work reproduced in detail the energetics of the explosion over nine orders of magnitude in spatial scale, from the surface of the star to its escape into the intergalactic medium.

The team found that explosions in low-density regions evicted all the gas from the protogalaxy on timescales of 25 million years. Such supernovae could engulf nearby protogalaxies, contaminating them with heavy elements. If the explosion instead occurs in a dense shroud like the one that gave birth to the star, it loses energy far more rapidly, briefly engulfing the protogalaxy but then collapsing back into it. This catastrophic fallback can fuel the rapid growth of a young black hole at the center of the protogalaxy, which may solve the long-standing puzzle of how supermassive black holes came to be in the centers of some galaxies less than a billion years after the Big Bang.

The research team

Los Alamos researchers include Daniel Whalen, Joseph Smidt, Jarrett Johnson, Wesley Even and Chris Fryer, with collaborators from the University of Edinburgh, Monash University, and University of Minnesota.

Laboratory Directed Research and Development (LDRD) funded the work. The scientists carried out the simulations on the Los Alamos Institutional Computing clusters Pinto and Mustang. Director’s Postdoctoral Fellowships sponsored Jarrett Johnson and Joseph Smidt. The work supports the Lab’s Information, Science, and Technology science pillar.